

HIGH-FREQUENCY CIRCUIT BOARD UNIT,  
HIGH-FREQUENCY MODULE USING THE SAME UNIT, ELECTRONIC  
APPARATUS USING THE SAME MODULE, AND MANUFACTURING  
METHOD FOR THE HIGH-FREQUENCY CIRCUIT BOARD UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a high-frequency circuit board unit, a high-frequency module using the same unit, and an electronic apparatus using the same module. The invention also relates to a manufacturing method for the above-described high-frequency circuit board unit.

5  
10  
15  
20  
25  
30  
35  
40  
45  
50  
55  
60  
65  
70  
75  
80  
85  
90  
95  
100  
105  
110  
115  
120  
125  
130  
135  
140  
145  
150  
155  
160  
165  
170  
175  
180  
185  
190  
195  
200  
205  
210  
215  
220  
225  
230  
235  
240  
245  
250  
255  
260  
265  
270  
275  
280  
285  
290  
295  
300  
305  
310  
315  
320  
325  
330  
335  
340  
345  
350  
355  
360  
365  
370  
375  
380  
385  
390  
395  
400  
405  
410  
415  
420  
425  
430  
435  
440  
445  
450  
455  
460  
465  
470  
475  
480  
485  
490  
495  
500  
505  
510  
515  
520  
525  
530  
535  
540  
545  
550  
555  
560  
565  
570  
575  
580  
585  
590  
595  
600  
605  
610  
615  
620  
625  
630  
635  
640  
645  
650  
655  
660  
665  
670  
675  
680  
685  
690  
695  
700  
705  
710  
715  
720  
725  
730  
735  
740  
745  
750  
755  
760  
765  
770  
775  
780  
785  
790  
795  
800  
805  
810  
815  
820  
825  
830  
835  
840  
845  
850  
855  
860  
865  
870  
875  
880  
885  
890  
895  
900  
905  
910  
915  
920  
925  
930  
935  
940  
945  
950  
955  
960  
965  
970  
975  
980  
985  
990  
995  
1000  
1005  
1010  
1015  
1020  
1025  
1030  
1035  
1040  
1045  
1050  
1055  
1060  
1065  
1070  
1075  
1080  
1085  
1090  
1095  
1100  
1105  
1110  
1115  
1120  
1125  
1130  
1135  
1140  
1145  
1150  
1155  
1160  
1165  
1170  
1175  
1180  
1185  
1190  
1195  
1200  
1205  
1210  
1215  
1220  
1225  
1230  
1235  
1240  
1245  
1250  
1255  
1260  
1265  
1270  
1275  
1280  
1285  
1290  
1295  
1300  
1305  
1310  
1315  
1320  
1325  
1330  
1335  
1340  
1345  
1350  
1355  
1360  
1365  
1370  
1375  
1380  
1385  
1390  
1395  
1400  
1405  
1410  
1415  
1420  
1425  
1430  
1435  
1440  
1445  
1450  
1455  
1460  
1465  
1470  
1475  
1480  
1485  
1490  
1495  
1500  
1505  
1510  
1515  
1520  
1525  
1530  
1535  
1540  
1545  
1550  
1555  
1560  
1565  
1570  
1575  
1580  
1585  
1590  
1595  
1600  
1605  
1610  
1615  
1620  
1625  
1630  
1635  
1640  
1645  
1650  
1655  
1660  
1665  
1670  
1675  
1680  
1685  
1690  
1695  
1700  
1705  
1710  
1715  
1720  
1725  
1730  
1735  
1740  
1745  
1750  
1755  
1760  
1765  
1770  
1775  
1780  
1785  
1790  
1795  
1800  
1805  
1810  
1815  
1820  
1825  
1830  
1835  
1840  
1845  
1850  
1855  
1860  
1865  
1870  
1875  
1880  
1885  
1890  
1895  
1900  
1905  
1910  
1915  
1920  
1925  
1930  
1935  
1940  
1945  
1950  
1955  
1960  
1965  
1970  
1975  
1980  
1985  
1990  
1995  
2000  
2005  
2010  
2015  
2020  
2025  
2030  
2035  
2040  
2045  
2050  
2055  
2060  
2065  
2070  
2075  
2080  
2085  
2090  
2095  
2100  
2105  
2110  
2115  
2120  
2125  
2130  
2135  
2140  
2145  
2150  
2155  
2160  
2165  
2170  
2175  
2180  
2185  
2190  
2195  
2200  
2205  
2210  
2215  
2220  
2225  
2230  
2235  
2240  
2245  
2250  
2255  
2260  
2265  
2270  
2275  
2280  
2285  
2290  
2295  
2300  
2305  
2310  
2315  
2320  
2325  
2330  
2335  
2340  
2345  
2350  
2355  
2360  
2365  
2370  
2375  
2380  
2385  
2390  
2395  
2400  
2405  
2410  
2415  
2420  
2425  
2430  
2435  
2440  
2445  
2450  
2455  
2460  
2465  
2470  
2475  
2480  
2485  
2490  
2495  
2500  
2505  
2510  
2515  
2520  
2525  
2530  
2535  
2540  
2545  
2550  
2555  
2560  
2565  
2570  
2575  
2580  
2585  
2590  
2595  
2600  
2605  
2610  
2615  
2620  
2625  
2630  
2635  
2640  
2645  
2650  
2655  
2660  
2665  
2670  
2675  
2680  
2685  
2690  
2695  
2700  
2705  
2710  
2715  
2720  
2725  
2730  
2735  
2740  
2745  
2750  
2755  
2760  
2765  
2770  
2775  
2780  
2785  
2790  
2795  
2800  
2805  
2810  
2815  
2820  
2825  
2830  
2835  
2840  
2845  
2850  
2855  
2860  
2865  
2870  
2875  
2880  
2885  
2890  
2895  
2900  
2905  
2910  
2915  
2920  
2925  
2930  
2935  
2940  
2945  
2950  
2955  
2960  
2965  
2970  
2975  
2980  
2985  
2990  
2995  
3000  
3005  
3010  
3015  
3020  
3025  
3030  
3035  
3040  
3045  
3050  
3055  
3060  
3065  
3070  
3075  
3080  
3085  
3090  
3095  
3100  
3105  
3110  
3115  
3120  
3125  
3130  
3135  
3140  
3145  
3150  
3155  
3160  
3165  
3170  
3175  
3180  
3185  
3190  
3195  
3200  
3205  
3210  
3215  
3220  
3225  
3230  
3235  
3240  
3245  
3250  
3255  
3260  
3265  
3270  
3275  
3280  
3285  
3290  
3295  
3300  
3305  
3310  
3315  
3320  
3325  
3330  
3335  
3340  
3345  
3350  
3355  
3360  
3365  
3370  
3375  
3380  
3385  
3390  
3395  
3400  
3405  
3410  
3415  
3420  
3425  
3430  
3435  
3440  
3445  
3450  
3455  
3460  
3465  
3470  
3475  
3480  
3485  
3490  
3495  
3500  
3505  
3510  
3515  
3520  
3525  
3530  
3535  
3540  
3545  
3550  
3555  
3560  
3565  
3570  
3575  
3580  
3585  
3590  
3595  
3600  
3605  
3610  
3615  
3620  
3625  
3630  
3635  
3640  
3645  
3650  
3655  
3660  
3665  
3670  
3675  
3680  
3685  
3690  
3695  
3700  
3705  
3710  
3715  
3720  
3725  
3730  
3735  
3740  
3745  
3750  
3755  
3760  
3765  
3770  
3775  
3780  
3785  
3790  
3795  
3800  
3805  
3810  
3815  
3820  
3825  
3830  
3835  
3840  
3845  
3850  
3855  
3860  
3865  
3870  
3875  
3880  
3885  
3890  
3895  
3900  
3905  
3910  
3915  
3920  
3925  
3930  
3935  
3940  
3945  
3950  
3955  
3960  
3965  
3970  
3975  
3980  
3985  
3990  
3995  
4000  
4005  
4010  
4015  
4020  
4025  
4030  
4035  
4040  
4045  
4050  
4055  
4060  
4065  
4070  
4075  
4080  
4085  
4090  
4095  
4100  
4105  
4110  
4115  
4120  
4125  
4130  
4135  
4140  
4145  
4150  
4155  
4160  
4165  
4170  
4175  
4180  
4185  
4190  
4195  
4200  
4205  
4210  
4215  
4220  
4225  
4230  
4235  
4240  
4245  
4250  
4255  
4260  
4265  
4270  
4275  
4280  
4285  
4290  
4295  
4300  
4305  
4310  
4315  
4320  
4325  
4330  
4335  
4340  
4345  
4350  
4355  
4360  
4365  
4370  
4375  
4380  
4385  
4390  
4395  
4400  
4405  
4410  
4415  
4420  
4425  
4430  
4435  
4440  
4445  
4450  
4455  
4460  
4465  
4470  
4475  
4480  
4485  
4490  
4495  
4500  
4505  
4510  
4515  
4520  
4525  
4530  
4535  
4540  
4545  
4550  
4555  
4560  
4565  
4570  
4575  
4580  
4585  
4590  
4595  
4600  
4605  
4610  
4615  
4620  
4625  
4630  
4635  
4640  
4645  
4650  
4655  
4660  
4665  
4670  
4675  
4680  
4685  
4690  
4695  
4700  
4705  
4710  
4715  
4720  
4725  
4730  
4735  
4740  
4745  
4750  
4755  
4760  
4765  
4770  
4775  
4780  
4785  
4790  
4795  
4800  
4805  
4810  
4815  
4820  
4825  
4830  
4835  
4840  
4845  
4850  
4855  
4860  
4865  
4870  
4875  
4880  
4885  
4890  
4895  
4900  
4905  
4910  
4915  
4920  
4925  
4930  
4935  
4940  
4945  
4950  
4955  
4960  
4965  
4970  
4975  
4980  
4985  
4990  
4995  
5000  
5005  
5010  
5015  
5020  
5025  
5030  
5035  
5040  
5045  
5050  
5055  
5060  
5065  
5070  
5075  
5080  
5085  
5090  
5095  
5100  
5105  
5110  
5115  
5120  
5125  
5130  
5135  
5140  
5145  
5150  
5155  
5160  
5165  
5170  
5175  
5180  
5185  
5190  
5195  
5200  
5205  
5210  
5215  
5220  
5225  
5230  
5235  
5240  
5245  
5250  
5255  
5260  
5265  
5270  
5275  
5280  
5285  
5290  
5295  
5300  
5305  
5310  
5315  
5320  
5325  
5330  
5335  
5340  
5345  
5350  
5355  
5360  
5365  
5370  
5375  
5380  
5385  
5390  
5395  
5400  
5405  
5410  
5415  
5420  
5425  
5430  
5435  
5440  
5445  
5450  
5455  
5460  
5465  
5470  
5475  
5480  
5485  
5490  
5495  
5500  
5505  
5510  
5515  
5520  
5525  
5530  
5535  
5540  
5545  
5550  
5555  
5560  
5565  
5570  
5575  
5580  
5585  
5590  
5595  
5600  
5605  
5610  
5615  
5620  
5625  
5630  
5635  
5640  
5645  
5650  
5655  
5660  
5665  
5670  
5675  
5680  
5685  
5690  
5695  
5700  
5705  
5710  
5715  
5720  
5725  
5730  
5735  
5740  
5745  
5750  
5755  
5760  
5765  
5770  
5775  
5780  
5785  
5790  
5795  
5800  
5805  
5810  
5815  
5820  
5825  
5830  
5835  
5840  
5845  
5850  
5855  
5860  
5865  
5870  
5875  
5880  
5885  
5890  
5895  
5900  
5905  
5910  
5915  
5920  
5925  
5930  
5935  
5940  
5945  
5950  
5955  
5960  
5965  
5970  
5975  
5980  
5985  
5990  
5995  
6000  
6005  
6010  
6015  
6020  
6025  
6030  
6035  
6040  
6045  
6050  
6055  
6060  
6065  
6070  
6075  
6080  
6085  
6090  
6095  
6100  
6105  
6110  
6115  
6120  
6125  
6130  
6135  
6140  
6145  
6150  
6155  
6160  
6165  
6170  
6175  
6180  
6185  
6190  
6195  
6200  
6205  
6210  
6215  
6220  
6225  
6230  
6235  
6240  
6245  
6250  
6255  
6260  
6265  
6270  
6275  
6280  
6285  
6290  
6295  
6300  
6305  
6310  
6315  
6320  
6325  
6330  
6335  
6340  
6345  
6350  
6355  
6360  
6365  
6370  
6375  
6380  
6385  
6390  
6395  
6400  
6405  
6410  
6415  
6420  
6425  
6430  
6435  
6440  
6445  
6450  
6455  
6460  
6465  
6470  
6475  
6480  
6485  
6490  
6495  
6500  
6505  
6510  
6515  
6520  
6525  
6530  
6535  
6540  
6545  
6550  
6555  
6560  
6565  
6570  
6575  
6580  
6585  
6590  
6595  
6600  
6605  
6610  
6615  
6620  
6625  
6630  
6635  
6640  
6645  
6650  
6655  
6660  
6665  
6670  
6675  
6680  
6685  
6690  
6695  
6700  
6705  
6710  
6715  
6720  
6725  
6730  
6735  
6740  
6745  
6750  
6755  
6760  
6765  
6770  
6775  
6780  
6785  
6790  
6795  
6800  
6805  
6810  
6815  
6820  
6825  
6830  
6835  
6840  
6845  
6850  
6855  
6860  
6865  
6870  
6875  
6880  
6885  
6890  
6895  
6900  
6905  
6910  
6915  
6920  
6925  
6930  
6935  
6940  
6945  
6950  
6955  
6960  
6965  
6970  
6975  
6980  
6985  
6990  
6995  
7000  
7005  
7010  
7015  
7020  
7025  
7030  
7035  
7040  
7045  
7050  
7055  
7060  
7065  
7070  
7075  
7080  
7085  
7090  
7095  
7100  
7105  
7110  
7115  
7120  
7125  
7130  
7135  
7140  
7145  
7150  
7155  
7160  
7165  
7170  
7175  
7180  
7185  
7190  
7195  
7200  
7205  
7210  
7215  
7220  
7225  
7230  
7235  
7240  
7245  
7250  
7255  
7260  
7265  
7270  
7275  
7280  
7285  
7290  
7295  
7300  
7305  
7310  
7315  
7320  
7325  
7330  
7335  
7340  
7345  
7350  
7355  
7360  
7365  
7370  
7375  
7380  
7385  
7390  
7395  
7400  
7405  
7410  
7415  
7420  
7425  
7430  
7435  
7440  
7445  
7450  
7455  
7460  
7465  
7470  
7475  
7480  
7485  
7490  
7495  
7500  
7505  
7510  
7515  
7520  
7525  
7530  
7535  
7540  
7545  
7550  
7555  
7560  
7565  
7570  
7575  
7580  
7585  
7590  
7595  
7600  
7605  
7610  
7615  
7620  
7625  
7630  
7635  
7640  
7645  
7650  
7655  
7660  
7665  
7670  
7675  
7680  
7685  
7690  
7695  
7700  
7705  
7710  
7715  
7720  
7725  
7730  
7735  
7740  
7745  
7750  
7755  
7760  
7765  
7770  
7775  
7780  
7785  
7790  
7795  
7800  
7805  
7810  
7815  
7820  
7825  
7830  
7835  
7840  
7845  
7850  
7855  
7860  
7865  
7870  
7875  
7880  
7885  
7890  
7895  
7900  
7905  
7910  
7915  
7920  
7925  
7930  
7935  
7940  
7945  
7950  
7955  
7960  
7965  
7970  
7975  
7980  
7985  
7990  
7995  
8000  
8005  
8010  
8015  
8020  
8025  
8030  
8035  
8040  
8045  
8050  
8055  
8060  
8065  
8070  
8075  
8080  
8085  
8090  
8095  
8100  
8105  
8110  
8115  
8120  
8125  
8130  
8135  
8140  
8145  
8150  
8155  
8160  
8165  
8170  
8175  
8180  
8185  
8190  
8195  
8200  
8205  
8210  
8215  
8220  
8225  
8230  
8235  
8240  
8245  
8250  
8255  
8260  
8265  
8270  
8275  
8280  
8285  
8290  
8295  
8300  
8305  
8310  
8315  
8320  
8325  
8330  
8335  
8340  
8345  
8350  
8355  
8360  
8365  
8370  
8375  
8380  
8385  
8390  
8395  
8400  
8405  
8410  
8415  
8420  
8425  
8430  
8435  
8440  
8445  
8450  
8455  
8460  
8465  
8470  
8475  
8480  
8485  
8490  
8495  
8500  
8505  
8510  
8515  
8520  
8525  
8530  
8535  
8540  
8545  
8550  
8555  
8560  
8565  
8570  
8575  
8580  
8585  
8590  
8595  
8600  
8605  
8610  
8615  
8620  
8625  
8630  
8635  
8640  
8645  
8650  
8655  
8660  
8665  
8670  
8675  
8680  
8685  
8690  
8695  
8700  
8705  
8710  
8715  
8720  
8725  
8730  
8735  
8740  
8745  
8750  
8755  
8760  
8765  
8770  
8775  
8780  
8785  
8790  
8795  
8800  
8805  
8810  
8815  
8820  
8825  
8830  
8835  
8840  
8845  
8850  
8855  
8860  
8865  
8870  
8875  
8880  
8885  
8890  
8895  
8900  
8905  
8910  
8915  
8920  
8925  
8930  
8935  
8940  
8945  
8950  
8955  
8960  
8965  
8970  
8975  
8980  
8985  
8990  
8995  
9000  
9005  
9010  
9015  
9020  
9025  
9030  
9035  
9040  
9045  
9050  
9055  
9060  
9065  
9070  
9075  
9080  
9085  
9090  
9095  
9100  
9105  
9110  
9115  
9120  
9125  
9130  
9135  
9140  
9145  
9150  
9155  
9160  
9165  
9170  
9175  
9180  
9185  
9190  
9195  
9200  
9205  
9210  
9215  
9220  
9225  
9230  
9235  
9240  
9245  
9250  
9255  
9260  
9265  
9270  
9275  
9280  
9285  
9290  
9295  
9300  
9305  
9310  
9315  
9320  
9325  
9330  
9335  
9340  
9345  
9350  
9355  
9360  
9365  
9370  
9375  
9380  
9385  
9390  
9395  
9400

filter 15 is mounted on the wiring electrode 6c formed on the second main surface of the dielectric substrate 3. The filter 15 is formed of a dielectric substrate 16 and a strip line electrode 17 is formed on the wiring electrode 6c and provided with a filtering function. The strip line electrode 17 and the wiring electrode 6d are connected to each other via a  
5 wire 10.

According to the high-frequency circuit board unit 1 constructed as described above, both the semiconductor device 8, which is an active device, and the filter 15, which is a passive device, are mounted on the circuit board 2. Accordingly, the circuit board unit 1 can be operated as a component having one function.

10            Generally, however, the semiconductor device 8, in particular, a GaAs semiconductor device, has a low breakdown voltage, and an electrostatic surge voltage may cause electrostatic discharge damage to the semiconductor device 8. Accordingly, in the high-frequency circuit board unit 1, if, for example, an electrostatic surge voltage is applied to the semiconductor device 8 via a signal line formed of the terminal electrode 15 5a, the through-hole 7a, the wiring electrode 6a, and the wire 10, the high-frequency circuit board unit 1 may be damaged.

          In particular, in a wireless-communication transceiver module using such a high-frequency circuit board unit, a terminal electrode connected to an antenna is exposed. Thus, if a surge voltage is applied to the circuit board unit via this terminal electrode, the  
20            semiconductor device may be damaged.

On the other hand, a surge voltage applied to the terminal electrode 5b via the filter 15 does not damage the semiconductor device 8 as long as the filter 15 is provides insulation between the input and output terminals.

Thus, in a semiconductor assembly line, for example, in which the semiconductor device 8 is mounted on the circuit board 2, sufficient measures must be taken against electrostatic damage regardless of the presence or the absence of the filter 15. However, this increases the cost of carrying out the process steps.

One way of protecting against electrostatic damage is to connect a surge-voltage protecting diode to a signal terminal of a semiconductor device. With this measure, however, the semiconductor device becomes expensive, and the diode may cause the loss of a high-frequency signal.

#### SUMMARY OF THE INVENTION

To solve the above-described problems, the present invention provides a high-frequency circuit board unit having a high breakdown voltage and thereby protected against an electrostatic surge voltage, a high-frequency module using such a high-frequency circuit board unit, an electronic apparatus using such a high-frequency module, and a manufacturing method for the high-frequency circuit board unit.

According to one aspect of the present invention, there is provided a high-frequency circuit board unit including a circuit board having a ground electrode and a terminal electrode. A semiconductor device is mounted on the circuit board, and includes

a high-frequency signal terminal for sending and receiving a high-frequency signal to and from the terminal electrode of the circuit board. At least one of the terminal electrode of the circuit board and the high-frequency signal terminal of the semiconductor device is connected to the ground electrode of the circuit board for conducting direct current.

5           The aforementioned high-frequency circuit board unit may further include a passive impedance circuit device mounted on the circuit board and connected between the high-frequency signal terminal and the terminal electrode. One of the high-frequency signal terminal and the terminal electrode may be connected to the ground electrode for conducting direct current via the passive impedance circuit device.

10          Alternatively, the aforementioned high-frequency circuit board unit may further include a passive impedance circuit device mounted on the circuit board and connected between the high-frequency signal terminal and the terminal electrode. Both the high-frequency signal terminal and the terminal electrode may be connected to the ground electrode for conducting direct current via the passive impedance circuit device.

15          The passive impedance circuit device may be formed on a dielectric substrate having a dielectric constant higher than that of a material of the circuit board or of the semiconductor device.

              The semiconductor device may be bump-mounted on the circuit board.

              An electrostatic protecting diode may be provided for a terminal other than the

20          high-frequency signal terminal of said semiconductor device.

5

According to another aspect of the present invention, there is provided a high-frequency module including the above-described high-frequency circuit board unit. The high-frequency module may have a cover. The circuit board may be used as a component mounting board for other components, and the terminal electrode may be used as an external terminal.

10 15

According to still another aspect of the present invention, there is provided an electronic apparatus including the above-described high-frequency circuit board unit or the aforementioned high-frequency module.

According to a further aspect of the present invention, there is provided a manufacturing method for a high-frequency circuit board unit. The manufacturing method includes the steps of: mounting, on a circuit board having a ground electrode and a terminal electrode, a passive impedance circuit device, at least one terminal of which is connected to the ground electrode for conducting direct current, in such a manner that at least one terminal is connected to the terminal electrode; and mounting a semiconductor device having a high-frequency signal terminal on the circuit board in such a manner that the high-frequency signal terminal is connected to the other terminal of the passive impedance circuit device.

In the aforementioned manufacturing method, the passive impedance circuit device and the semiconductor device may be bump-mounted on the circuit board.

At least one terminal of said passive impedance circuit device may be connected to said ground electrode after said semiconductor device is mounted on said circuit board.

Further, at least one terminal of said passive impedance circuit device may be connected to said ground electrode before said high-frequency signal terminal is connected to said other terminal of said passive impedance circuit device.

The high-frequency circuit board unit, the high-frequency module, and the electronic apparatus of the present invention provide a high breakdown voltage against an electrostatic surge voltage. Thus, the reliability can be improved, and the size of the high-frequency circuit board unit can be reduced.

According to the manufacturing method for the high-frequency circuit board of the present invention, the possibility of electrostatic discharge damage while manufacturing the semiconductor device can be reduced. As a result, the manufacturing process can be simplified, and the cost of the high-frequency circuit board unit can be reduced.

Other features and advantages of the present invention will become apparent from the following description of embodiments of the invention which refers to the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view illustrating a high-frequency circuit board unit according to an embodiment of the present invention;

Fig. 2 is a perspective view illustrating an example of a filter mounted on a high-frequency circuit board unit of the present invention;

Fig. 3A illustrates a manufacturing process for a high-frequency circuit board unit of the present invention in which the filter shown in Fig. 2 is mounted on a circuit board;

5 Fig. 3B illustrates the manufacturing process for the high-frequency circuit board unit of the present invention in which a semiconductor device is mounted on the circuit board provided with the filter;

Fig. 4 is a perspective view illustrating another example of the filter mounted on a high-frequency circuit board unit of the present invention;

10 Fig. 5 is a perspective view illustrating still another example of the filter mounted on a high-frequency circuit board unit of the present invention;

Fig. 6 is a sectional view illustrating a high-frequency circuit board unit according to another embodiment of the present invention;

15 Fig. 7 is a plan view illustrating another example of the semiconductor device mounted on a high-frequency circuit board unit of the present invention;

Fig. 8 is a sectional view illustrating a high-frequency module according to an embodiment of the present invention;

Fig. 9 is a block diagram schematically illustrating the high-frequency module shown in Fig. 8;

20 Fig. 10 is a partially cutaway perspective view illustrating an electronic apparatus

according to an embodiment of the present invention; and

Fig. 11 is a sectional view illustrating a conventional high-frequency circuit board unit.

5        DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Fig. 1 is a sectional view illustrating a high-frequency circuit board unit according to an embodiment of the present invention. In Fig. 1, elements the same as or similar to those of Fig. 11 are designated with like reference numerals, and an explanation thereof will thus be omitted.

10        In a high-frequency circuit board unit 20 shown in Fig. 1, the semiconductor device 8 and a filter 30, which serves as a passive impedance circuit device, are connected to a plurality of wiring electrodes 6a, 6b, 6c, 6d which are formed on the second main surface of the dielectric substrate 3. Unlike the conventional high-frequency circuit board unit 1 shown in Fig. 11, the wiring electrode 6a connected to the connecting land 8b via the wire 10 is not connected to a terminal electrode on the first main surface of the dielectric substrate 3.

15        Fig. 2 is a perspective view illustrating the filter 30. In Fig. 2, the filter 30 includes a dielectric substrate 31, a ground electrode 32, a strip line electrode 33, and a through-hole 34. The dielectric substrate 31 has a dielectric constant of, for example, 20 110, higher than that of the material of the dielectric substrate 3 (having a dielectric constant of about 9 if it is an alumina substrate) or the material of the semiconductor

device 8 (having a dielectric constant of about 12.5 if it is a GaAs device). The ground electrode 32 is formed on the first main surface of the dielectric substrate 31. The strip line electrode 33 is formed on the second main surface of the dielectric substrate 31. The through-hole 34 is used for connecting the ground electrode 32 and the strip line electrode 5 33. The strip line electrode 33 is formed of a line and a 1/4-wavelength stub connected to the central portion of the line. The forward end of the stub is connected to the ground electrode 32 by the through-hole 34, and is thus grounded. Accordingly, the stub serves as a short stub. The two ends of the line, which serve as an input terminal and an output terminal, are connected to the wiring electrodes 6b, and 6d of the high-frequency circuit 10 board unit 20 shown in Fig. 1 via the wires 10.

The above-configured filter 30 serves as a band-pass filter which allows a specific frequency corresponding to the length of the short stub to pass there through. Since the forward end of the short stub is connected to the ground electrode 32 via the through-hole 34, the input and output terminals (connected to the input/output wires) of the filter 30 are 15 connected to the ground electrode 32 for conducting direct current.

In the filter 30, the strip line electrode 33 is formed on the dielectric substrate 31 having a dielectric constant that is much higher than that of the material of the dielectric substrate 3 or the semiconductor device 8. In this case, the wavelength shortening coefficient which is applied to the strip line electrode 33 becomes much higher than if 20 the strip line electrode were directly formed on the dielectric substrate 3 or the

semiconductor device 8, thereby significantly reducing the size of the line electrode. As a result, the filter 30 can be significantly miniaturized.

A manufacturing method for the high-frequency circuit board unit 20 shown in Fig. 1 is described below with reference to Figs. 3A and 3B. Elements the same as or 5 similar to those shown in Fig. 1 and Fig. 2 are indicated by like reference numerals, and an explanation thereof will thus be omitted.

In a first process step, as shown in Fig. 3A, the filter 30 is mounted on the predetermined wiring electrode 6c, which is connected to the ground electrode 4 of the circuit board 2 via the through-hole 7, and the input/output terminals of the filter 30 are 10 connected to the wiring electrodes 6b and 6d on the circuit board 2 by the wires 10. In this case, the ground electrode 32 of the filter 30 is electrically connected to the wiring electrode 6c by soldering or die bonding using a conductive material, and is thus grounded. As discussed above, as shown in Fig. 2, the input/output terminals of the filter 30 are connected to the ground electrode 32 for conducting direct current. Accordingly, 15 the input/output terminals of the filter 30 are also connected to the ground electrode 4 of the circuit board 2 for conducting direct current. That is, the wiring electrode 6c of the circuit board 2 connected to the filter 30 is connected to the ground electrode 4 via the through-hole 7 for conducting direct current to/from the filter 30.

In a second process step, as shown in Fig. 3B, the semiconductor device 8 is 20 mounted on the circuit board 2, and the connecting lands 8a, 8b of the semiconductor

device 8 are connected to the wiring electrodes 6b, 6a of the circuit board 2 by the wires 10.

The connecting lands of the semiconductor device 8 include a connecting land 8a, which serves as a high-frequency signal terminal for sending and receiving a high- 5 frequency signal to and from an external source; and a connecting land 8b, which serves as the other terminal, such as a power supply terminal, through which a high-frequency signal is not sent or received.

The connecting land 8a, which is a high-frequency signal terminal of the semiconductor device 8, is coupled to the wiring electrode 6b connected to the filter 30. 10 As discussed in the first process step, the wiring electrode 6b is connected to the ground electrode 4 via the filter 30 for conducting direct current. Accordingly, even if, for example, an electrostatic surge voltage is applied to the terminal electrode 5 for some reason while the semiconductor device 8 is being mounted, it is grounded via the filter 30 before reaching the semiconductor device 8. Thus, the semiconductor device 8 can be 15 protected from electrostatic discharge damage. With this arrangement, it is not necessary to take elaborate measures against electrostatic damage, and thus, the cost of managing the process steps is reduced.

In a preferred embodiment of the process, in order to integrate the die bonding step and the wire bonding step, the connection of the input/output terminals of the filter 20 30 to the wiring electrodes 6b, 6d on the circuit board 2 by the wires 10 in the first

process step is performed after the semiconductor device 8 is mounted on the circuit board 2 and before the connecting lands 8a and 8b of the semiconductor device 8 are connected to the wiring electrodes 6b, 6a by the wires 10 in the second process step. According to this preferred process, the filter 30 has already been mounted when the 5 connecting lands 8a and 8b of the semiconductor device 8 are coupled to the wiring electrodes 6b, 6a by the wires 10. Accordingly, the wiring electrodes 6b, 6d connected to the filter 30 are connected to the ground electrode 4 for conducting direct current via the filter 30. Thus, advantages similar to those obtained by connecting the filter 30 to the wiring electrodes 6b, 6d by wire bonding before the mounting of the semiconductor 10 device 8 can be exhibited.

Referring back to Fig. 1, in the high-frequency circuit board unit 20 constructed as described above, both the terminal electrode 5 of the circuit board 2 and the connecting land 8a, which is the high-frequency signal terminal of the semiconductor device 8, are connected to the ground electrode 4 for conducting direct current via the filter 30. Accordingly, the high-frequency circuit board unit 20 has a high breakdown voltage, and even if an electrostatic surge voltage is applied to the terminal electrode 5 for some reason, electrostatic discharge damage to the semiconductor device 8 does not occur. Thus, the reliability of the high-frequency circuit board unit 20 is improved.

Additionally, the strip line electrode 33 is formed on the dielectric substrate 31

having a dielectric constant higher than that of the dielectric substrate 3 forming the circuit board 2. Thus, the size of the filter 30 can be reduced, and the entire high-frequency circuit board unit 20 thereby be considerably miniaturized.

Another example of a filter, which serves as a passive impedance circuit device, 5 for use in the high-frequency circuit board unit of the present invention is shown in Fig. 4. In Fig. 4, elements the same as or similar to those shown in Fig. 2 are designated with like reference numerals, and an explanation thereof will thus be omitted.

In Fig. 4, a filter 35 includes a linear 1/2-wavelength strip line electrode 36 on the 10 second main surface of the dielectric substrate 31. The central portion of the strip line electrode 36 is connected to the ground electrode 32 via the through-hole 34. The wires 10 are connected to the strip line electrode 36 at respective positions between the center and the ends of the strip line electrode 36, which positions serve as the input and output terminals.

In the above-configured filter 35, both the ends of the strip line electrode 36 are 15 operated as 1/4-wavelength resonators. The two resonators are coupled to each other via an inductance component of the through-hole 34 so that they serve as band-pass filters for allowing specific frequencies to pass there through. Additionally, the central portion of the strip line electrode 36 is connected to the ground electrode 32 via the through-hole 34. Accordingly, the input/output terminals (strip line electrode 36 connected to the 20 input/output wire 10) are connected to the ground electrode 32 for conducting direct

current.

Fig. 5 illustrates still another example of the filter, which is a passive impedance circuit device, for use in the high-frequency circuit board unit of the present invention. In Fig. 5, elements the same as or similar to those shown in Fig. 4 are indicated by like reference numerals, and an explanation thereof will thus be omitted.

A filter 40 shown in Fig. 5 is different from the filter 35 shown in Fig. 4 only in that a non-linear or S-shaped strip line electrode 41 is provided instead of the linear strip line electrode 36.

In the above-configured filter 40, the individual portions of the strip line electrode 41 are coupled to each other, thereby improving filtering characteristics, such as reducing spurious characteristics, and also making the filter 40 smaller than the filter 35.

As in the filter 30 shown in Fig. 2, in the filters 35 and 40 shown in Figs. 4 and 5, respectively, the input/output terminals are connected to the ground electrode 32 for conducting direct current. Accordingly, when the filter 35 or 40 is mounted on the high-frequency circuit board unit of the present invention, advantages similar to those exhibited by the filter 30 can be obtained.

Fig. 6 is a sectional view illustrating a high-frequency circuit board unit according to another embodiment of the present invention. In Fig. 6, elements the same as or similar to those shown in Fig. 1 are designated with like reference numerals, and an explanation thereof will thus be omitted.

In a high-frequency circuit board unit 50 shown in Fig. 6, the semiconductor device 8 and the filter 30, which is a passive impedance circuit device, are bump-mounted (flip-chip mounted) on the wiring electrodes 6a, 6b, 6c, 6d formed on the second main surface of the dielectric substrate 3. A bump 8c is provided on each of the terminals 8a and 8b of the semiconductor device 8, and the terminals 8a and 8b are connected to the wiring electrodes 6a, 6b via the bumps 8c. In the filter 30, too, three bumps 30a are provided on the strip line electrode 33, and the filter 30 is connected to the wiring electrodes 6b, 6c, 6d via the bumps 30a. With this configuration, the wires (bonding wires) 10 provided for the high-frequency circuit board unit 20 shown in Fig. 1 are not necessary.

As discussed above, in the high-frequency circuit board unit 50, the semiconductor device 8 and the filter 30 are bump-mounted on the wiring electrode 6, thereby eliminating the wire bonding process. This decreases the possibility of causing electrostatic discharge damage.

Fig. 7 is a plan view illustrating another example of a semiconductor device for being mounted on the high-frequency circuit board unit of the present invention. In a semiconductor device 60 shown in Fig. 7, various circuit elements (not shown) and connecting lands 62, 63, 64, and 65 connected to these circuit elements are formed on a semiconductor chip 61. The connecting land 62 serves as a power supply input terminal, the connecting land 63 is used as a ground terminal, and the connecting lands 64 and 65

serve as high-frequency signal terminals. An electrostatic protecting diode 66 is formed between the connecting lands 62 and 63.

By providing the electrostatic protecting diode 66 for the connecting lands 62 and 63, which are not the high-frequency signal terminals, the breakdown voltage against a 5 surge voltage applied to the connecting lands 62 and 63 of the semiconductor device 60 can be increased. Additionally, since an electrostatic protecting diode is not needed for the connecting lands 64 and 65, which are high-frequency signal terminals, the loss of the high-frequency signal due to such diode can be prevented. According to the high-frequency circuit board unit using the above-configured semiconductor device 60, it is 10 possible to reduce the possibility of causing electrostatic discharge damage to the semiconductor device 60 when a surge voltage is applied via a path other than a path for transmitting a high-frequency signal.

In the high-frequency circuit board units of the foregoing embodiments, a filter is used as the passive impedance circuit device. However, another type of device without 15 active filtering characteristics, such as a matching circuit, may be used as the passive impedance circuit device. In this case, advantages similar to those obtained by the filter can also be obtained.

Fig. 8 is a sectional view illustrating a high-frequency module according to an embodiment of the present invention. In Fig. 8, elements the same as or similar to those 20 shown in Fig. 1 are indicated by like reference numerals, and an explanation thereof will

thus be omitted. Fig. 9 is a block diagram schematically illustrating a wireless communication transceiver module which is one example of high-frequency module of Fig. 8.

In a high-frequency module 70 shown in Fig. 8, a cover 71 for covering the 5 semiconductor device 8 and the filter 30 is placed on the high-frequency circuit board unit 20. In this case, the terminal electrode 5 of the high-frequency circuit board unit 20 serves as an external terminal.

Referring to the block diagram of Fig. 9, the high-frequency module 70 is formed of a local oscillator LO, high-frequency switches SW1 and SW2, mixers MIX1 and 10 MIX2, a power amplifier PA, a low noise amplifier LNA, and the filter 30. Among these elements, the local oscillator LO, the high-frequency switches SW1 and SW2, the mixers MIX1 and MIX2, the power amplifier PA, and the low noise amplifier LNA are formed on the semiconductor device 8.

The local oscillator LO is connected to a first terminal of the high-frequency 15 switch SW1, and second and third terminals of the high-frequency switch SW1 are connected to the mixers MIX1 and MIX2, respectively. The mixer MIX1 is connected to a second terminal of the high-frequency switch SW2 via the power amplifier PA. A first terminal of the switch SW2 is connected via the filter 30 to an antenna ANT separately provided for the high-frequency module 70. A third terminal of the high-frequency 20 switch SW2 is connected to the mixer MIX2 via the low noise amplifier LNA.

The operation of the high-frequency module 70 is briefly discussed below. An IF signal is input into the mixer MIX1 from a transmitter circuit (not shown). When the first terminal of the high-frequency switch SW1 is connected to the second terminal of the switch SW1, a carrier signal is input into the mixer MIX1 from the local oscillator LO.

5      Accordingly, the carrier signal is modulated with the IF signal input into the mixer MIX1, and the resulting signal is output from the mixer MIX1 as an RF signal. The RF signal is then amplified in the power amplifier PA, and is input into the second terminal of the high-frequency switch SW2. The high-frequency switch SW2 is operated in cooperation with the high-frequency switch SW1. More specifically, when the first terminal and the second terminal of the high-frequency switch SW1 are connected, the first terminal and the second terminal of the high-frequency switch SW2 are also connected. Accordingly, the RF signal input into the second terminal of the high-frequency switch SW2 is output from the first terminal. Then, the RF signal is input into the filter 30 in which unwanted signal components are eliminated, and the resulting RF signal is radiated from the

10     antenna ANT as radio waves.

15     On the other hand, an the RF signal received by the antenna ANT is input into the filter 30 in which unwanted signal components are eliminated. Then, when the first terminals of the high-frequency switches SW1 and SW2 are connected to the corresponding third terminals, the resulting RF signal is input into the low noise amplifier LNA via the high-frequency switch SW2, and is amplified. The RF signal is then input

into the mixer MIX2. A carrier signal output from the local oscillator LO has been input into the mixer MIX2 via the high-frequency switch SW1. Thus, the carrier signal components are removed from the RF signal in the mixer MIX2, and the resulting signal is input into a receiver circuit (not shown) as an IF signal.

5        In the above-configured high-frequency module 70, an electrostatic surge voltage may be applied via the terminal connected to the antenna ANT. However, the surge voltage is shunted to the ground electrode 4 of the circuit board 2 via the filter 30. Thus, the local oscillator LO, the high-frequency switches SW1 and SW2, the mixers MIX1 and MIX2, the power amplifier PA, and the low noise amplifier LNA of the semiconductor device 8 can be protected from electrostatic discharge damage. Accordingly, the high-frequency module 70 can be safely used even in a manufacturing line in which measures against electrostatic discharge damage are not sufficiently taken.

10

15        Although not shown in Fig. 9, a protective diode like that in Fig. 7 may be provided as well in the embodiment of Figs. 8-9 and in any other embodiment of the invention.

Fig. 10 is a perspective view illustrating an electronic apparatus according to an embodiment of the present invention. In Fig. 10, a cellular telephone 80, which is an example of the electronic apparatus of the present invention, includes a casing 81, a printed board 82 disposed in the casing 81, and a high-frequency module 83 of the present invention mounted on the printed board 82. The high-frequency module 83 is a

20

high frequency component, such as an amplifier, an oscillator, or a filter.

Since the high-frequency module 83 of the present invention is used, the above-configured cellular telephone 80 is protected from electrostatic discharge damage. It is thus possible to simplify the anti-electrostatic measures taken in the manufacturing process, thereby decreasing the cost and improving the reliability.

The cellular telephone 80 shown in Fig. 10 is a mere example of the electronic apparatus of the present invention. The invention includes any electronic apparatus using the high-frequency module of the present invention.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. Therefore, the present invention is not limited by the specific disclosure herein, but only by the appended claims.